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U.S. NONPROVISIONAL PATENT APPLICATION

METHOD AND SYSTEM FOR CREATING AN IMAGE OF A RADIATION SOURCE

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METHOD AND SYSTEM FOR CREATING AN IMAGE OF A RADIATION SOURCE

Field of the Invention

[0001] The present invention relates to creating an image of a radiation source, and more specifically, to a method and a system for creating an image of a radiation source.

Background of the Invention

[0002] In medical imaging, such as in Nuclear Medicine, a radioactive material, such as a radioactive tracer, is introduced into an object or a body to view parts of the object or body. The parts of the body that receive the radioactive material act as a radiation source for emitting radiation. A system for creating an image of the radiation source includes a detector for detecting radiation associated with the radiation source. The detector may be a gamma camera, a positron emission tomography (PET) camera, a solid state detector, or an x-ray detector. The spatial resolution and contrast of the image generated by these systems are limited by the intrinsic resolution or point spread function of the detector and the number of photons recorded by the detector. As a result, there is an inherent and well-known blurriness to nuclear medicine images.

[0003] Those in the industry will be familiar with the standard method for calibrating radiation detectors, specifically nuclear medicine detectors. A flood source of gamma rays are illuminated onto the detector, for example, a sodium iodine crystal, through a plate of spaced holes so as to produce non-overlapping point spread functions. These allow the specific calibration and creation of a table of correction factors needed for the specific crystal detector. Since the precise location of the holes is known, the corrections can be applied to maximize the apparent linearity and normalize the point spread function of the crystal. Still, the best calibration and correction factors cannot eliminate the inherent point spread function due to the random nature of the detector.

[0004] Consequently, a significant need exists for a way to sharpen nuclear medicine images.

Brief Summary of the Invention

[0005] A method of creating an image of a radiation source includes detecting radiation associated with a first location of the radiation source. Data corresponding to the radiation associated with the first location is processed to provide a first value. The first value is employed to generate a first portion of the image associated with the first location. Radiation associated with a second location of the radiation source is detected. Data corresponding to the radiation associated with the second location is processed to provide a second value. The second value is employed to generate a second portion of the image associated with the second location.

[0006] In accordance with one feature, a system for creating the image of the radiation source includes an aggregator for aggregating the data corresponding to radiation associated with the first location of the radiation source to provide the first value. The aggregator aggregates the data corresponding to radiation associated with the second location of the radiation source to provide the second value. A mapping system maps the first value to a first portion of the image associated with the first location and maps the second value to a second portion of the image associated with the second location. These and other objects and advantages of the present invention shall be made apparent from the accompanying drawings and the description thereof.

Brief Description of the Figures

[0007] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and, together with the general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the present invention.

[0008] FIG. 1 is a schematic view of a portion of an imaging system for creating an image of a radiation source;

[0009] FIG. 2 is a schematic view of the imaging system of FIG. 1;

[0010] FIG. 3 is a plan view of a first embodiment of a plate member for use in the imaging system of FIG. 2;

[0011] FIG. 4 is a plan view of a second embodiment of a plate member for use in the system in FIG. 2;

[0012] FIG. 5 is a plan view of a third embodiment of a plate member for use in the imaging system in FIG. 2; and

[0013] FIG. 6 is a plan view of a portion of a fourth embodiment of a plate member for use in the imaging system in FIG. 2.

[0014] FIG. 7 is a schematic view of a prior art source imaging system;

[0015] FIG. 8 is a schematic view of the imaging system of FIG. 1 showing how a collimator with a guard band allows resolution of the point spread function to a single aperture; and

[0016] FIG. 9A is a schematic view of a plate member comprised of a plate with aperture diameter D1 and a collimator cylinder with diameter D1 and length L. for the system of FIG. 1.

[0017] FIG. 9B is a schematic view of a plate member comprised of a plate with aperture diameter D1 and a collimator cylinder with diameter D2 > D1 but less than the guard band diameter, and length L. for the system of FIG. 1.

[0018] FIG. 9C is a schematic view of a plate member comprised of a first plate with aperture diameter D1 and a collimator cylinder with diameter D2 > D1 but less than the guard band diameter and length L, and a second plate identical to first plate for the system of FIG. 1.

Detailed Description of the Invention

[0019] The present invention is directed to a method and a system for creating an image of a radiation source. A system for creating an image of a radiation source is illustrated in FIGS. 1-3. The imaging system 10 (FIG. 1) includes a detector 12. The detector 12 detects radiation 14, such as ionizing radiation, emitted from a radiation source 16. The system 10 may be used in medical imaging to create an image of the radiation source 16. The detector 12 may include a collimator, a crystal, photo multipliers, and/or solid state detector elements as known in the art. The detector 12 may be any suitable detector, such

as a gamma camera, a positron emission tomography (PET) camera, a solid state detector, or an x-ray detector.

[0020] A plate member 22 is located between the detector 12 and the radiation source 16. The plate member 22 is made of a suitable radiation absorbing material, such as lead, and includes a plurality of apertures 24. It is contemplated that the plate member 22 may have any desired thickness. It is also contemplated that the plate member 22 may be used as a collimator for the detector 12. The radiation 14 from the radiation source 16 only passes through the apertures 24 in the plate member 22 to the detector 12. Accordingly, the detector 12 only detects radiation 28 that passes through the apertures 24.

[0021] The apertures 24 (FIG. 3) are arranged in the plate member 22 in a predetermined pattern of a series of rows and columns. The plate member 22 may have any desired number of rows and columns of apertures 24. Furthermore, the apertures 24 may be arranged in any desired pattern. It is also contemplated that the plate member 22 may have any desired number of apertures 24.

[0022] The apertures 24 (FIG. 3) are identical to each other. Each of the apertures 24 is square shaped. Each of the apertures 24 in the plate member 22 has a first dimension d1 measured in an x direction. Each of the apertures 24 has a second dimension d2 measured in a y direction. The first dimension d1 is equal to the second dimension d2. The dimensions d1 and d2 are smaller than the intrinsic resolution or point spread function of the detector 12. It is contemplated that the apertures 24 may have any desired shape, such as circular, triangular, rectangular or hexagonal. Furthermore, the apertures 24 may not be identical to each other, may vary in size and shape and be arranged in configurations other than a rectangular pattern, if desired.

[0023] The apertures 24 are spaced from each other in the x direction by septa of a distance s1. The apertures 24 are spaced from each other in the y direction by septa of a distance s2. The distance s1 is equal to the distance s2. It is contemplated that the distance s1 may not be equal to the distance s2. Each of the distances s1 and s2 is equal to two times the dimension d1. Accordingly, each of the distances s1 and s2 is equal to two times the dimension d2. Each of the distances s1 and s2 is larger than the intrinsic resolution of the detector 12. Accordingly, each of the apertures 24 has a guard band surrounding the aperture. It is contemplated that the distance s1 may be equal to any

integer times the dimension d1 and that the distance s2 may be equal to any integer times the dimension d2.

[0024] Each of the apertures 24 (FIG. 1) is associated with a location of the radiation source 16. The locations of the radiation source 16 have sizes equal to the sizes of the apertures 24. Radiation 28 associated with each of the locations of the radiation source 16 passes through the apertures 24 to the detector 12 while the plate member 22 prevents passage of radiation from the radiation source 16 at locations not associated with the apertures 24. The detector 12 detects or samples the radiation 28 associated with each of the locations of the radiation source 16. Accordingly, the detector 12 detects radiation 28 associated with a first location of the radiation source 16 that passes through a first aperture 24 in the plate member 22. The detector 12 also detects radiation 28 associated with a second location of the radiation source 16 that passes through a second aperture 24 that is spaced from the first aperture 24.

[0025] A positioning mechanism 36 is connected with the plate member 22 to move the plate member 22 in the x direction or a first linear direction relative to the detector 12 and the radiation source 16. The positioning mechanism 36 also moves the plate member 22 in the y direction or a second linear direction relative to the detector 12 and the radiation source 16. The positioning mechanism 36 moves the plate member 22 in a stepwise manner relative to the detector 12 and the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 22 in a continuous linear motion in the x direction and a continuous linear motion in the y direction. The positioning mechanism 36 may be any suitable positioning mechanism for moving the plate member 22 relative to the detector 12 and the radiation source 16, such as an electric motor or manually operable mechanism. It is contemplated that any number of positioning mechanisms 36 may be used to move the plate member 22.

[0026] The positioning mechanism 36 moves the plate member 22 relative to the detector 12 and the radiation source 16 so that the detector 12 detects radiation 28 associated with every location of the radiation source 16. The positioning mechanism 36 moves the plate member 22 in the x direction in steps having a distance equal to the dimension d1. The positioning mechanism 36 moves the plate member 22 in the y direction in steps having a distance equal to the dimension d2. The positioning mechanism 36 positions the plate

member 22 in nine steps in the x and y directions so that the detector 12 detects radiation from every location of the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 22 any suitable number of steps relative to the detector 12 and the radiation source 16. Furthermore, the positioning mechanism 36 may move the plate member 22 in the x direction in steps having a distance equal to a fraction of the dimension d1 and in the y direction in steps having a distance equal to a fraction of the dimension d2. It is also contemplated that the positioning mechanism 36 may rotate the plate member 22 relative to the detector 12 and the radiation source 16.

[0027] The detector 12 (FIG. 2) is operably connected with a computer 50. The computer 50 receives image data 52 from the detector 12. An imaging application 54 processes the image data 52 corresponding to the radiation 28 associated with the locations of the radiation source 16 to provide a plurality of image values. The imaging application 54 employs the image values to generate portions of the image associated with the locations of the radiation source 16.

[0028] The imaging application 54 includes an aggregator 56 for processing the image data 52. The aggregator 56 aggregates the image data 52 corresponding to the radiation associated with the locations of the radiation source 16 to provide the image values. A mapping system 58 of the imaging application 54 maps the image values to corresponding portions of the image.

[0029] The computer 50 is operably connected to a display 62 for displaying the image. An apparatus 64 is operably connected to the computer 50 for inputting user input, such as the locations and sizes of the apertures 24 in the plate member 22. Other devices 68 may also be operably connected to the computer 50, such as a printer, a computer network, and/or the internet. It is also contemplated that the positioning mechanism 36 may be operably connected to the computer 50. The computer 50 may operate the positioning mechanism 36 to move the plate member 22 relative to the detector 12 and the radiation source 16.

[0030] The system 10 (FIGS. 1 and 2) operates to create an image of the radiation source 16 by positioning the plate member 22 in a first position relative to the detector 12 and the radiation source 16. The detector 12 detects or samples radiation 28 from the radiation source 16 passing through the apertures 24 in the plate member 22. The

detector 12 detects radiation 28 associated with a first set of locations of the radiation source 16. The radiation 28 that passes through the apertures 24 in the plate member 22 is detected by the detector 12. The detector 12 produces Gaussian-like distributions or events of image data 52. The distributions of image data 52 are generally spread over an area that is greater than the area of the apertures 24. The distributions of data do not overlap since the apertures 24 are spaced apart with guard bands by distances s1 and s2 that are larger than the intrinsic resolution or point spread function of the detector 12. It is contemplated that the distances s1 and s2 may be chosen such that the distributions may overlap. Accordingly, the detector 12 detects radiation 28 associated with a first location of the radiation source 16 that passes through a first one of the apertures 24. The detector 12 also detects radiation 28 associated with a second location of the radiation source 16 that passes through a second one of the apertures 24.

[0031] The image data 52 associated with the first set of locations is processed by the imaging application 54. The image data 52 corresponding to the radiation 28 associated with the first set of locations of the radiation source 16 is processed by the aggregator 56 to provide a first set of image values. Accordingly, the aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the first location of the radiation source 16 to produce a first image value. The aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the second location to produce a second image value. The aggregator 56 may sum up the values of each of the distributions to provide each of the image values. Accordingly, the statistical noise associated with each of the image values is minimal. A sample image of the radiation source 16 may be generated.

[0032] If the distributions of image data 52 overlap, the imaging application 54 may correct the image values using experimentally determined or estimated contributions from the adjacent distributions.

[0033] After the detector 12 detects the radiation 28 associated with the first set of locations of the radiation source 16 with the plate member 22 in the first position, the positioning mechanism 36 moves the plate member in the x direction a distance equal to the dimension d1 into a second position. The detector 12 detects radiation 28 from the radiation source 16 passing through the apertures 24 in the plate member 22. The

detector 12 detects radiation 28 associated with a second set of locations of the radiation source 16. The radiation 28 that passes through the apertures 24 in the plate member 22 is detected by the detector 12. The detector 12 produces distributions of image data 52. Accordingly, the detector 12 detects radiation associated with a third location of the radiation source 16 that passes through the first one of the apertures 24. The detector 12 also detects radiation 28 associated with a fourth location of the radiation source 16 that passes through the second one of the apertures 24.

[0034] The image data 52 associated with the second set of locations is processed by the imaging application 54. The image data 52 corresponding to the radiation 28 associated with the second set of locations of the radiation source 16 is processed by the aggregator 56 to provide a second set of image values. Accordingly, the aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the third location of the radiation source 16 to produce a third image value. The aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the fourth location to produce a fourth image value. A second sample image of the radiation source 16 may be generated.

[0035] After the detector 12 detects the radiation 28 associated with the second set of locations of the radiation source 16 with the plate member 22 in the second position, the positioning mechanism 36 moves the plate member in the y direction a distance equal to the dimension d2 into a third position. The detector 12 detects radiation 28 from the radiation source 16 passing through the apertures 24 in the plate member 22. The detector 12 detects radiation 28 associated with a third set of locations of the radiation source 16. The radiation 28 that passes through the apertures 24 in the plate member 22 is detected by the detector 12. The detector 12 produces distributions of image data 52. Accordingly, the detector 12 detects radiation associated with a fifth location of the radiation source 16 that passes through the first one of the apertures 24. The detector 12 also detects radiation 28 associated with a sixth location of the radiation source 16 that passes through the second one of the apertures 24.

[0036] The image data 52 associated with the third set of locations is processed by the imaging application 54. The image data 52 corresponding to the radiation 28 associated with the third set of locations of the radiation source 16 is processed by the aggregator

56 to provide a third set of image values. Accordingly, the aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the fifth location of the radiation source 16 to produce a fifth image value. The aggregator 56 aggregates the image data 52 corresponding to the radiation 28 associated with the sixth location to produce a sixth image value. A third sample image of the radiation source 16 may be generated.

[0037] The steps of moving the plate member 22, detecting radiation 28 associated with a set of locations, and processing the image data 52 associated with the set of locations is repeated until radiation associated with every location of the radiation source 16 is detected. The steps need to be repeated at least nine times to detect radiation 28 from every location of the radiation source 16. The number of steps that are needed to detect radiation emitted from every location of the radiation source 16 is a function of the size of the apertures 24 in the plate member 22 and the distances s1 and s2 between the apertures. It is contemplated that any number of steps could be used to detect radiation emitted from every location of the radiation source.

[0038] The mapping system 58 employs the image values to generate the image of the radiation source 16. The mapping system 58 maps the image values to portions or pixels of the image that correspond to the locations of the radiation source 16. Each of the portions of the image has an area that is equal to the area of the aperture 24 in the plate member 22. The image values in each of the portions of the image do not contain data associated with any other locations of the radiation source 16. Accordingly, the spatial resolution of the system 10 is equal to the size of the apertures 24 in the plate member 22 and is independent of the spatial resolution or point spread function of the detector 12.

[0039] The mapping system 58 maps the first image value to a first portion of the image that corresponds to the first location of the radiation source 16. The first portion of the image has an area that is equal to the area of the aperture 24 in the plate member 22. The image value in the first portion of the image does not contain any data associated with any other locations of the radiation source 16. The mapping system 58 maps the second image value to a second portion of the image that corresponds to the second location of the radiation source 16. The second portion of the image has an area that is equal to the area of the aperture 24 in the plate member 22. The image value in the second portion of

the image does not contain any data associated with any other locations of the radiation source 16. The mapping system 58 maps all the image values to corresponding portions of the image. Accordingly, the image has a resolution equal to the size of the apertures 24 in the plate member 22, which may be smaller than the intrinsic resolution of the detector 12. The image also has an improved contrast since each of the portions of the image does not include data associated with any other locations of the radiation source 16.

[0040] It is contemplated that each of the portions of the image may include a minimal amount of data associated with another location of the radiation source 16. It is contemplated that if the distributions of image data 52 overlap, the imaging application 54 may correct the image values using experimentally determined or estimated contributions from the adjacent distributions.

[0041] A plate member 122 constructed in accordance with a second embodiment for use in the system shown in FIGS. 1-2 is illustrated in FIG. 4. The plate member 122 shown in FIG. 4 is made of a suitable radiation absorbing material, such as lead, and includes a plurality of apertures 124. It is contemplated that the plate member 122 may have any desired thickness. It is also contemplated that the plate member 122 may be used as a collimator for the detector 12. The detector 12 only detects radiation 28 that passes through the apertures 124.

[0042] The apertures 124 are arranged in the plate member 122 in a predetermined pattern. The apertures 124 are arranged in a series of rows and columns. The plate member 122 may have any desired number of rows and columns of apertures 124. Furthermore, the apertures 124 may be arranged in any desired pattern. It is also contemplated that the plate member 122 may have any desired number of apertures 124.

[0043] The apertures 124 are identical to each other. Each of the apertures 124 is square shaped. Each of the apertures 124 in the plate member 122 has a first dimension d3 measured in an x direction. Each of the apertures 124 has a second dimension d4 measured in a y direction. The first dimension d3 is equal to the second dimension d4. The dimensions d3 and d4 are smaller than the intrinsic resolution or point spread function of the detector 12. It is contemplated that the apertures 124 may have any desired shape, such as circular, triangular, rectangular or hexagonal. Furthermore, the

apertures 124 may not be identical to each other and may vary in size and shape if desired.

[0044] The apertures 124 are spaced from each other in the x direction by septa of a distance s3. The apertures 124 are spaced from each other in the y direction by septa of a distance s4. An aperture 124 in one row is not spaced in the y direction from the apertures in the adjacent rows. Adjacent columns are spaced from each other in the x direction by a distance s5 that is equal to the distance s4. The distance s3 is equal to eight times the dimension d3. The distance s4 is equal to two times the dimension d4. The distance s5 is equal to two times the dimension d3. The distances s3, s4, and s5 are larger than the intrinsic resolution of the detector 12. Accordingly, each of the apertures 124 has a guard band surrounding the aperture 124. It is contemplated that the distance s3 may be equal to any integer times the dimension d3. It is contemplated that the distance s4 may be equal to any integer times the dimension d4 and that the distance s5 may be equal to any integer times the dimension d3.

[0045] Each of the apertures 124 is associated with a location of the radiation source 16. The locations of the radiation source 16 have sizes equal to the sizes of the apertures 124. The radiation 28 associated with each of the locations of the radiation source 16 passes through the apertures 124 to the detector 12 while the plate member 122 prevents passage of radiation 14 from the radiation source 16 at locations not associated with the apertures 124. The detector 12 detects or samples the radiation 28 associated with each of the locations of the radiation source 16. Accordingly, the detector 12 detects radiation 28 associated with a first location of the radiation source 16 that passes through a first aperture 124 in the plate member 122. The detector 12 also detects radiation 28 associated with a second location of the radiation source 16 that passes through a second aperture 124 that is spaced from the first aperture 124.

[0046] The positioning mechanism 36 is connected with the plate member 122 to move the plate member in the x direction or a first linear direction relative to the detector 12 and the radiation source 16. The positioning mechanism 36 moves the plate member 122 in a stepwise manner relative to the detector 12 and the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 122 in a continuous linear motion in the x direction.

[0047] The positioning mechanism 36 moves the plate member 122 relative to the detector 12 and the radiation source 16 so that the detector 12 detects radiation 28 associated with every location of the radiation source 16. The positioning mechanism 36 moves the plate member 122 in the x direction in steps having a distance equal to the dimension d3. The positioning mechanism 36 positions the plate member 122 in nine steps in the x direction so that the detector 12 detects radiation 28 from every location of the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 122 any suitable number of steps relative to the detector 12 and the radiation source 16. Furthermore, the positioning mechanism 36 may move the plate member 122 in steps having a distance equal to a fraction of the dimension d3. Accordingly, the positioning mechanism 36 only moves the plate member 122 in one linear direction so that the detector 12 detects radiation 28 from every location of the radiation source 16.

[0048] A plate member 222 constructed in accordance with a third embodiment for use in the system 10 shown in FIGS. 1-2 is illustrated in FIG. 5. The plate member 222 shown in FIG. 5 is made of a suitable radiation absorbing material, such as lead, and includes a plurality of apertures 224. It is contemplated that the plate member 222 may have any desired thickness. It is also contemplated that the plate member 222 may be used as a collimator for the detector 12. The detector 12 only detects radiation 28 that passes through the apertures 224. The apertures 224 are arranged in the plate member 222 in a predetermined pattern. The apertures 224 are arranged in a honeycomb pattern. The apertures 224 may be arranged in any desired pattern. It is contemplated that the plate member 222 may have any desired number of apertures 224.

[0049] The apertures 224 are identical to each other. Each of the apertures 224 is hexagonal shaped. Each of the apertures 224 has a size smaller than the intrinsic resolution of the detector 12. The apertures 224 are spaced from each other so that each aperture has a hexagonal space 226 equal in size to the aperture to each side of the aperture that does not overlap a hexagonal space to a side of another aperture. The distances between the apertures 224 are larger than the intrinsic resolution of the detector 12. Accordingly, each of the apertures 224 has a guard band surrounding the aperture 224. It is contemplated that the apertures 224 may have any desired shape, such as

circular, triangular, rectangular or square shaped. Furthermore, the apertures 224 may not be identical to each other and may vary in size and shape if desired.

[0050] Each of the apertures 224 is associated with a location of the radiation source 16. The locations of the radiation source 16 have sizes equal to the sizes of the apertures 224. The radiation 28 associated with each of the locations of the radiation source 16 passes through the apertures 224 to the detector 12 while the plate member 222 prevents passage of radiation 24 from the radiation source 16 at locations not associated with the apertures 224. The detector 12 detects or samples the radiation 28 associated with each of the locations of the radiation source 16. Accordingly, the detector 12 detects radiation 28 associated with a first location of the radiation source 16 that passes through a first aperture 224 in the plate member 222. The detector 12 also detects radiation 28 associated with a second location of the radiation source 16 that passes through a second aperture 224 that is spaced from the first aperture 224.

[0051] The positioning mechanism 36 is connected with the plate member 222 to move the plate member 222 relative to the detector 12 and the radiation source 16. The positioning mechanism 36 moves the plate member 222 in a stepwise manner relative to the detector 12 and the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 222 in a continuous motion.

[0052] The positioning mechanism 36 moves the plate member 222 relative to the detector 12 and the radiation source 16 so that the detector 12 detects radiation 28 associated with every location of the radiation source 16. The positioning mechanism 36 moves the plate member 222 in steps having a distance equal to the size of the apertures 224. The positioning mechanism 36 positions the plate member 222 in at least seven steps so that the detector 12 detects radiation 28 from every location of the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 222 any suitable number of steps relative to the detector 12 and the radiation source 16.

[0053] Furthermore, the positioning mechanism 36 may move the plate member 222 in steps having a distance equal to a fraction of the size of the apertures 224.

[0054] The positioning mechanism 36 may move the plate member 222 in one linear direction extending perpendicular to sides of the apertures 224 so that the detector 12 detects radiation 28 from every location of the radiation source 16.

[0055] The positioning mechanism 36 may also move the plate member 222 in one linear direction extending diagonally to the sides of the apertures 224 so that the detector 12 detects radiation from every location of the radiation source 16.

[0056] The positioning mechanism 36 may move the plate member 222 in a spiral pattern so that the detector 12 detects radiation from every location of the radiation source 16.

[0057] A portion of a plate member 322 constructed in accordance with a fourth embodiment for use in the system shown in FIGS. 1-2 is illustrated in FIG. 6. The plate member 322 shown in FIG. 6 is made of a suitable radiation absorbing material, such as lead, and includes a plurality of apertures 324. It is contemplated that the plate member 322 may have any desired thickness. It is also contemplated that the plate member 322 may be used as a collimator for the detector 12. The detector 12 only detects radiation 28 that passes through the apertures 324.

[0058] The apertures 324 are arranged in the plate member 322 in a predetermined pattern. The apertures 324 are arranged in a series of rows and columns. The plate member 322 may have any desired number of rows and columns of apertures 324. Furthermore, the apertures 324 may be arranged in any desired pattern. It is also contemplated that the plate member 322 may have any desired number of apertures 324.

[0059] The apertures 324 are identical to each other. Each of the apertures 324 is square shaped. Each of the apertures 324 in the plate member 322 has a first dimension d5 measured in an x direction. Each of the apertures 324 has a second dimension d6 measured in a y direction. The first dimension d5 is equal to the second dimension d6. The dimensions d5 and d6 are smaller than the intrinsic resolution or point spread function of the detector 12. It is contemplated that the apertures 324 may have any desired shape, such as circular, triangular, rectangular or hexagonal. Furthermore, the apertures 324 may not be identical to each other and may vary in size and shape if desired.

[0060] The apertures 324 are spaced from each other in the x direction by septa of a distance s6. The apertures 324 are spaced from each other in the y direction by septa of a distance s7. The distances s6 and s7 are equal to each other and the dimensions d5 and d6. Accordingly, each of the apertures 324 has a guard band surrounding the aperture 324.

[0061] Each of the apertures 324 is associated with a location of the radiation source 16. The locations of the radiation source 16 have sizes equal to the sizes of the apertures 324. The radiation 28 associated with each of the locations of the radiation source 16 passes through the apertures 324 to the detector 12 while the plate member 322 prevents passage of radiation 14 from the radiation source 16 at locations not associated with the apertures 324. The detector 12 detects or samples the radiation 28 associated with each of the locations of the radiation source 16. Accordingly, the detector 12 detects radiation 28 associated with a first location of the radiation source 16 that passes through a first aperture 324 in the plate member 322. The detector 12 also detects radiation 28 associated with a second location of the radiation source 16 that passes through a second aperture 324 that is spaced from the first aperture 324.

[0062] The positioning mechanism 36 is connected with the plate member 322 to move the plate member 322 in the x direction or a first linear direction relative to the detector 12 and the radiation source 16. The positioning mechanism 36 also moves the plate member 322 in the y direction relative to the detector 12 and the radiation source 16. The positioning mechanism 36 moves the plate member 322 in a stepwise manner relative to the detector 12 and the radiation source 16. It is contemplated that the positioning mechanism 36 may move the plate member 322 in a continuous motion.

[0063] The positioning mechanism 36 moves the plate member 322 relative to the detector 12 and the radiation source 16 so that the detector 12 detects radiation 28 associated with every location of the radiation source 16. The positioning mechanism 36 moves the plate member 322 in the x direction in steps having a distance equal to the dimension d5. The positioning mechanism 36 moves the plate member 322 in the y direction in steps having a distance equal to the dimension d6. The positioning mechanism 36 positions the plate member 322 in four steps in the x and y directions so that the detector 12 detects radiation 28 from every location of the radiation source 16. It

is contemplated that the positioning mechanism 36 may move the plate member 322 any suitable number of steps relative to the detector 12 and the radiation source 16. Furthermore, the positioning mechanism 36 may move the plate member 322 in the x direction in steps having a distance equal to a fraction of the dimension d5 and in the y direction in steps having a distance equal to a fraction of the dimension d6.

[0064] The plate member 322 is ideally suited for use with a solid state detector (not shown), such as a cadmium zinc telluride detector. The solid state detector has an array of detector elements that are generally square in cross-section. The apertures 324 in the plate 322 have a size equal to one quarter the size of the detector elements. It is contemplated that the apertures 324 may be any desired fractional size of the detector elements. The apertures 324 are positioned to expose only one quadrant of the detector elements at a time. The plate member 322 is subsequently positioned to expose different quadrants of the detector elements until the detector 12 detects radiation 28 from every location of the radiation source 16.

[0065] The plate member 322 is also ideally suited for use with a small solid state or gas microstrip detectors (not shown), in which case the apertures 324 in the plate 322 can have a single aperture per detector element. It is contemplated that the apertures 324 may be any desired fractional size of the detector element. The apertures 324 and detector element are positioned together. The combined plate member 322 and detector is subsequently positioned until the detector detects radiation 28 from every location of the radiation source 16.

[0066] The size of the apertures 24, 124, 224, and 324 in the plate members 22, 122, 222, and 322 determine the spatial resolution of the system 10. The smaller the apertures 24, 124, 224, and 324 the better the spatial resolution. Accordingly, the spatial resolution or point spread function of the detector 12 does not determine the spatial resolution of the system 10. The distances between the apertures 24, 124, 224, and 324 determine the contrast of the system 10. The larger the distances between the apertures 24, 124, 224, and 324 the better the contrast. If the apertures 24, 124, 224, and 324 are relatively small and the distances between the apertures are relatively large, a greater number of steps are needed to detect radiation 28 from every location of the radiation source 16.

[0067] Each image value provided by the aggregator 56 of the system 10 has a statistical noise. The statistical noise associated with each image value is defined as the inverse of the square root of the image value. The image values provided by the aggregator 56 are generated by summing the values of each of the distributions. Therefore, the image values provided by the aggregator 56 are larger than or equal to image values obtained by not summing the values of the distributions. Accordingly, the image generated by using the image values provided by the aggregator 56 of the system 10 has less statistical noise.

[0068] Although the plate members 22, 122, 222, and 322 are described as being located between the radiation source 16 and the detector 12, it is contemplated that the plate members 22, 122, 222, 322 may be used instead of the collimator of the detector 12.

[0069] Although the positioning mechanism 36 moves the plate members 22, 122, 222, and 322 relative to the radiation source 16 and the detector 12 so that the detector 12 detects radiation 28 associated with every location of the radiation source 16, it is contemplated that the positioning mechanism 36 may move the plate members 22, 122, 222, 322 such that the detector 12 does not detect radiation 28 associated with every location of the radiation source. The imaging application 54 may estimate the image values that correspond to the locations of the radiation source 16 that are not detected. The mapping system 58 may map the estimated image values to corresponding portions of the image.

[0070] It is contemplated that the plate members 22, 122, 222, and 322 may be fixed to the detector 12, such as a rotating SPECT (single photon emission computer tomography) camera (not shown). A positioning mechanism may rotate the detector 12 and the plate member fixed to the detector relative to the radiation source 16 about an axis extending parallel to the plate member. The detector 12 and the plate member fixed to the detector may be rotated in a continuous or stepwise manner around the radiation source 16. The rotation of the detector 12 and the plate member fixed to the detector permits the detection of radiation 28 from every location of the radiation source 16 from multiple angles around the axis of rotation of the detector. The computer 50, using various mathematical techniques, may construct transaxial cross sections through the radiation source 16.

[0071] It is contemplated that the plate members 22, 122, 222, and 322 may be fixed to the detector 12, and a positioning mechanism may move the radiation source relative to the detector 12. The radiation source may be moved in the reverse direction of any of the patterns described above, depending on the plate member. The movement of the radiation source permits the detection of radiation 28 from every location of the radiation source 16 by the detector. The computer 50, using various mathematical techniques, may construct transaxial cross sections through the radiation source 16.

[0072] FIG. 7 illustrates a traditional medical application 400 in which a patient (radiation source) 402 emits gamma radiation 404 that passes through parallel hole collimator 406, to become collimated gamma radiation 408 that falls upon a detector, depicted as a gamma camera 410. Because the septa around a traditional collimator 406 is made as thin as possible given the radiation energy, the point spread functions of collimator holes 412 overlap, blurring the image. The overlapping reduces contrast and resolution. If the collimator septa 414 were sufficiently increased in thickness to form a guard band 416 around each collimator hole 412, as illustrated in FIG. 8, then the point spread functions could be made separable, so that each detected photon could be assigned to a specific hole 418 in a collimator 420 (e.g., plate/collimator combination, single collimator construction). However, the large guard band 416 would block much of the source radiation 904, so that only an incomplete image would be created that most likely would be corrupted by Moire patterns. This can be fixed by stepping or in some way moving the collimator 406 in a suitable pattern to expose the detector 410 to the entire radiation source 402. This creates a series of images which, when appropriately mapped and composited, form a complete image of the source radiation with resolution and contrast only limited by collimator hole size and septal thickness.

[0073] Those experienced in the art will appreciate the many forms in which such a collimator may be constructed. For illustration purposes only, FIGS. 9A-9C show a simplified plate-collimator configuration, in which the plate member takes the form of a flat plate or plates with precisely placed apertures joined to a parallel hole collimator. Only a single aperture and collimator hole are depicted.

[0074] FIG. 9A shows a cone 490 indicating the possible source locations and lower extreme defined by upper photons 500, 502 for radiation 504 passing through a first

opaque plate with aperture 508 having diameter D1 plate 506 and collimator hole 510. The cone 490 approaches a true parallel ray collimator as the collimator depth, or hole length L, becomes infinitely large, and/or as the collimator hole diameter D1 becomes infinitely small thereby reducing a diameter of a zone of incidence 512 on a detector 514. In this version, the plate aperture 508 and the collimator hole 510 are of equal internal diameter D1. The effective member aperture for these illustrations is defined as that aperture comprised of a plate and collimator combination with both having the same internal diameter A1, and without loss of generality, length L. Hence A1 = D1 in this case.

[0075] In FIG. 9B, if the plate aperture diameter D1 is made smaller than the diameter of the collimator hole 508 D2 (and D2 is smaller than the guard band diameter), then the effective member aperture A2 has a diameter greater than D1. To obtain the same effective member aperture as D1, then a second identical plate 530 can be added to the opposite side of the collimator. This is illustrated in FIG. 9C, wherein A3 = D1. It will be appreciated by those practiced in the art of collimator design that these principles will allow for construction methods that minimize the total weight of the plate member, while allowing the aperture diameter to become small.

[0076] It will become apparent to those practiced in the art that if the apertures are relatively small and the distances between the apertures are relatively large, a greater number of steps are needed to detect radiation 28 from every location of the radiation source 16. This creates a tradeoff between the increase in resolution and contrast, and the amount of time required to obtain an image. Four approaches can mitigate the need for increased time, and potentially even reduce the total time.

[0077] The first approach tries to reduce the septal distance. Parametric and nonparametric methods exist to allow inference of the distributions of partially overlapping point spread functions, such as Bayesion modeling, neural networks, linear discriminants, etc.

[0078] The second approach increases the detector size. Many detectors are constrained in size to avoid "flooding". In gamma cameras, simultaneous events (two or more gamma rays striking simultaneously) are rejected since they cannot each be simultaneously localized. A large detector increases the likelihood of such an

occurrence. The present invention, with its guard bands blocking the majority of the source radiation from reaching the detector, can accommodate a much large detector before flooding will occur. Thus, while more time is required at each placement of the member, data can be collected over a larger area.

[0079] A third approach is to sacrifice some of the increased contrast and resolution by collecting less data at each member position than would otherwise be done with a standard system.

[0080] A fourth approach is to increase the intensity of the source radiation, so that less time needs to be spent at each member position. The consequence in a medical imaging application would be a higher radiation exposure to the patient.

[0081] There are clear tradeoffs that can be optimized using these four approaches.

[0082] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications may readily appear to those skilled in the art. For example,

[0083] What is claimed is:

Claims

1. A method of creating an image of a radiation source comprising:

detecting radiation associated with a first location of the radiation source; processing data corresponding to the radiation associated with the first location to provide a first value;

employing the first value to generate a first portion of the image associated with the first location;

detecting radiation associated with a second location of the radiation source;

processing data corresponding to the radiation associated with the second location to provide a second value; and

employing the second value to generate a second portion of the image associated with the second location.

2. A method as set forth in claim 1 further including:

detecting radiation associated with a first location of the radiation source having a size that is smaller than the resolution of a detector used for detecting the radiation but not smaller than the resolution of a collimator used with the detector; and

detecting radiation associated with a second location of the radiation source having a size that is smaller than the resolution of the detector but not smaller than the resolution of the collimator.

3. A method as set forth in claim 1 further including:

detecting radiation associated with a first location of the radiation source having a resolution that is smaller than the resolution of a detector used for detecting the radiation and also smaller than the resolution of a collimator used with the detector; and

detecting radiation associated with a second location of the radiation source having a resolution that is smaller than the resolution of the detector and also smaller than the resolution of the collimator.

4. A method as set forth in claim 1 further including:

providing a member for preventing radiation associated with a third location of the radiation source from being detected, said member

(a) being placed between the radiation source and a detector for detecting radiation and

(b) having an aperture through which radiation associated with the first and second locations passes.

5. A method as set forth in claim 4 further including:

(a) detecting radiation associated with a first location located substantially adjacent to a second location while preventing detection of radiation associated with the second location and

(b) detecting radiation associated with the second location while preventing detection of radiation associated with the first location.

6. A method as set forth in claim 4 further including:

placing the member in a first position relative to the detector while detecting radiation associated with the first location and

placing the member in a second position relative to the detector while detecting radiation associated with the second location.

7. A method as set forth in claim 6 further including moving the member and the detector relative to each other in only one linear direction from the first position to the second position.

8. A method as set forth in claim 4 further including:

placing the member in a first position relative to the radiation source while detecting radiation associated with the first location and

placing the member in a second position relative to the radiation source while detecting radiation associated with the second location.

9. A method as set forth in claim 4 further including providing the aperture in the member with a size smaller than the resolution of the detector but not smaller than the resolution of the collimator.

10. A method as set forth in claim 4 further including providing the aperture in the member with a size smaller than the resolution of the detector and smaller than the resolution of the collimator.

11. A method as set forth in claim 1 further including:

providing a member for preventing radiation associated with a third location of the radiation source from being detected,

said member

(a) being placed between the radiation source and a detector for detecting radiation and

(b) having first and second apertures spaced from each other through which radiation associated with the first and second locations passes.

12. A method as set forth in claim 11 further including simultaneously detecting radiation associated with the first and second locations.

13. A method as set forth in claim 1 further including summing values of a distribution of data corresponding to the radiation associated with the first location to provide the first value.

14. A method as set forth in claim 13 further including summing values of a distribution of data corresponding to the radiation associated with the second location to provide the second value.

15. A system for creating an image of a radiation source comprising:

an aggregator for aggregating data corresponding to radiation associated with a first location of the radiation source to provide a first value,

said aggregator aggregating data corresponding to radiation associated with a second location of the radiation source to provide a second value;

a mapping system for mapping the first value to a first portion of the image associated with the first location and

for mapping the second value to a second portion of the image associated with the second location.

16. A system as set forth in claim 15 further including a detector for detecting the radiation associated with the first and second locations.

17. A system as set forth in claim 16 further including:

a member for preventing radiation associated with a third location of the radiation source from being detected between the radiation source and

the detector having an aperture through which radiation associated with the first and second locations passes.

18. A system as set forth in claim 17 wherein said aperture has a size smaller than the resolution of the detector

but not smaller than the resolution of a collimator used with the detector.

19. A system as set forth in claim 18 wherein said aperture has a size smaller than the resolution of the detector and smaller than the resolution of a collimator used with the detector.

20. A system as set forth in claim 18 further including means for moving the member relative to the radiation source and detector.

21. A system as set forth in claim 18 further including means for moving the member and the radiation source relative to each other.

22. A system as set forth in claim 16 further including:

a member for preventing radiation associated with a third location of the radiation source from being detected between the radiation source and

the detector having first and second apertures spaced from each other through which radiation associated with the first and second locations passes.

23. A system as set forth in claim 22 wherein each of said first and second apertures has a size smaller than the resolution of the detector but not smaller than the resolution of a collimator used with the detector.

24. A system as set forth in claim 22 wherein each of said first and second apertures has a size smaller than the resolution of the detector and smaller than the resolution of a collimator used with the detector.

25. A system as set forth in claim 22 further including means for moving the member relative to the radiation source and detector.

26. A system as set forth in claim 22 further including means for moving the member and the radiation source relative to each other.